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Contribution of the VISTA-ITL Program for the Standard Design Approval of the SMART Design

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1. Introduction

A small-scale integral effect test (IET) program had been performed by the Korea Atomic Energy Research Institute (KAERI) using the VISTA integral test loop (VISTA-ITL) [1]. It has the simulation capability of small-break loss of coolant accident (SBLOCA), complete loss of reactor coolant system (RCS) flow (CLOF) and passive residual heat removal system (PRHRS) performance for the SMART design. The reference plant of the VISTA-ITL is a 330-MWth integral pressurized water reactor (iPWR), SMART [2], which was developed by KAERI. Its standard design had been approved by Korean regulatory authority on July 2012.

The SMART reactor is characterized by the introduction of simplified and improved safety systems such as passive residual heat removal system (PRHRS) and its integral arrangement of the reactor vessel assembly. Integral reactor design eliminates the large-size pipe connections between major components. Thus, it excludes the occurrence of a large break loss of coolant accident (LBLOCA), and a SBLOCA is one of major concerns for safety analysis. Therefore, the VISTA-ITL was used to investigate various thermal-hydraulic phenomena during the SBLOCA. The break flow rate, safety injection flow rate, and thermal-hydraulic behaviors of major components were measured for a typical break size and break locations. The acquired data was used to validate related thermal-hydraulic models of the safety analysis code, TASS/SMR-S [3] which is used to validate the safety of the SMART in coping with the SBLOCA scenarios.

A set of tests for SBLOCAs, CLOF and PRHRS performance was performed to understand the general behavior and to assess its safety of the SMART design using the VISTA-ITL facility. The test results were used to validate the TASS/SMR-S code. This paper also introduces regulatory issues concerning the VISTA-ITL tests and how they were resolved. The scoping analysis was performed in resolving regulatory issues using a best-estimate system analysis code, MARS-KS [5] developed by KAERI.

2. Scaling and Basic Design of the VISTA-ITL

The VISTA-ITL is a 1/2.77-height, 1/1310-volume scaled test facility based on the design features of SMART. The reference scale ratios of height (1/2.77) and area (1/472.9) are based on the elevation difference between core and steam generator centers and the core flow area, respectively. The existing VISTA facility was modified to have the simulation capability of SBLOCA by installing the steam pressurizer, the safety injection system and the break simulation system, etc. The rationale for adoption of the reduced-height design is similar to the ATLAS design [4]. As the scale ratio of length is 1/2.77, the time for the VISTA-ITL is 1.664 times faster than that for the SMART design. Both scale ratios of core power and flow rate are 1/787, and the scale ratio of pressure drop is 1/2.77. Fig. 1 shows the schematics of the VISTA-ITL facility.

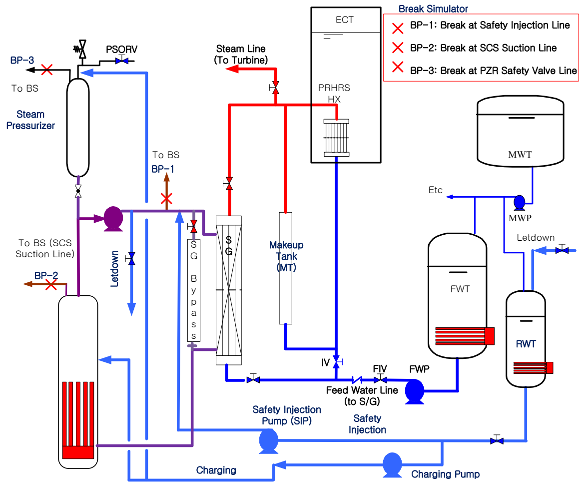

Fig. 1 Schematic diagram of the VISTA-ITL facility

3. Major Tests using the VISTA-ITL

3.1 SBLOCA simulation

Three SBLOCA tests were successfully performed and provided for validating the TASS/SMR-S code. The break types are guillotine breaks, and their break locations are at the safety injection system (SIS) line (nozzle part of the RCP discharge), at the suction line of the shutdown cooling system (SCS) (nozzle part of the RCP suction), and the pressurizer safety valve (PSV) line connected to the pressurizer top. Additional SBLOCA tests were performed for various initial and boundary conditions and for examining the PRHRS performance during the licensing process.

3.2 CLOF simulation

A CLOF test was successfully performed and provided for validating the TASS/SMR-S code. Additional test was performed during the licensing process.

3.3 PRHRS performance

PRHRS performance verification tests were performed for 100% scaled power, 20% scaled power and hot standby condition, respectively. It was demonstrated that two-phase natural circulation in the PRHRS was properly achieved at different initial powers and feed-water flow rates. The PRHRS performance was also investigated for SBLOCA conditions.

4. Licensing Issues on the VISTA-ITL Program

4.1 Scaling of the VISTA-ITL

First of all, the questions were mainly focused on the scaling and basic design of the VISTA-ITL.

- Proper scaling of major scaling parameters: length, area, volume, flow rate, heat flux, etc.
- Similarity of major components between the VISTA-ITL and the SMART: Existing VISTA design & newly equipped design of makeup tank, SI nozzle, steam pressurizer, surge line, break flowrate measuring system, SG bypass and SIS pump
- Similarity of steam generator and PRHRS HX in terms of heat transfer coefficient
- Similarity of RCP in terms of geometric difference
- Design criteria of the break nozzle and break line for SBLOCA simulation

These questions are resolved by providing following analysis.

- Scoping analysis for scaling distortion and similarity assessment between the VISTA-ITL and the SMART using the MARS/KS code
- Parametric assessment of geometric scaling distortion: heated core length, PRHRS HX length, elevation difference between SG and PRHRS centers, heat transfer areas of SG and PRHRS HX, feedwater temperature and flow rate, heat structures of primary and secondary systems, break line, differential pressure across surge line, and mass inventory distortion

4.2 Similarity between the SMART and the VISTA-ITL

Analysis results of the MARS/KS and the TASS/SMR-S codes were compared.

- Analysis of the SMART design using the MARS/KS and TASS/SMR-S codes
- Analysis of the VISTA-ITL test data using both the MARS/KS and TASS/SMR-S codes
- Analysis of the SMART design and the VISTA-ITL test data using the MARS/KS and comparison between them

4.3 Assessment of the VISTA-ITL test data

The similarity of the VISTA-ITL test data was directly compared with the SMART design.

- Review on the trip signals (LPP, HPP, PRHRAS, SIAS) and setpoints used during VISTA-ITL tests and analysis on their sensitivity
- Effect of LPP setpoint on pressurizer pressure and core heater surface temperature
- Repeatability of the VISTA-ITL test results (A3, A3R)
- Analysis of direct similarity between the SMART design and the VISTA-ITL test data
- Assessment of the VISTA-ITL test results: For example, the RCS flow rate during transients were not measured due to small flow rate and it was estimated from heat and mass balance.

4.4 Simulation Capability of the MARS/KS code

The capability of the MARS/KS code was validated. As the MARS code has the simulation capability on major thermal-hydraulic phenomena during the SBLOCA scenario of the SMART, it could be used to analyze the SMART design and the VISTA ITL test data.

- Applicability of the MARS-KS to SMART SBLOCA scenario
- MARS/KS analysis on POSTECH SG tests
- MARS/KS analysis on POSTECH PRHRS HX tests

5. Conclusions

There were lots of licensing questions and answers on various technical fields during the licensing phase of the SMART SDA. Among them, the questions and answers concerning the VISTA-ITL program were summarized and their resolution was discussed in this paper. The VISTA-ITL program contributed to the SMART SDA by providing test data for validating the TASS-SMR code.

ACKNOWLEDGEMENTS

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